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Status of the Black-capped Vireo at Fort Hood, Texas, Volume II: Habitat

by
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The black-capped vireo is an endangered species that resides at Fort Hood, TX during the summer breeding season. A 3-year ecological status survey of the vireo was conducted on Fort Hood from 1987 through 1989 as part of the effort to fully comply with the Endangered Species Act. The two other reports in this series focus on vireo distribution and abundance, and population and nesting ecology.

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The black-capped vireo is an endangered species that resides at Fort Hood, TX during the summer breeding season. A 3-year ecological status survey of the vireo was conducted on Fort Hood from 1987 through 1989 as part of the effort to fully comply with the Endangered Species Act. The two other reports in this series focus on vireo distribution and abundance, and population and nesting ecology.

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FOREWORD

This study was conducted for Headquarters (HQ) III Corps and Fort Hood under Intra-Agency Orders (IAOs) 348-87, 66-88, and 268-88; for Assistant Chief of Staff for Installation Management (ACSIM) under Funding Acquisition document (FAD) 89-080046; and HQ, Forces Command under Military Interdepartmental Purchase Request (MIPR) JE26-91.

The work was performed by the Environmental Natural Resources Division (EN) of the Environmental Sustainment Laboratory (EL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Dr. David Tazik, Dr. William D. Severinghaus is Acting Chief, CECER-EN, and William D. Goran is Acting Chief, CECER-EL. David St. George and Beth St. George of Mabion, WA, collected the vireo habitat data. Dan Salzer and Geralyn Larkin of Portland, OR, assisted in locating and mapping vireo territories, and, with Dr. Gary Schnell and Dan Hough (Oklahoma Biological Survey, Norman, OK) assisted in computerization of the habitat data. Dennis Herbert and B.R. Jones (Fish and Wildlife Branch, Environmental Division, Fort Hood) were most helpful in identifying potential vireo colony sites, coordinating research activities, assisting researchers in gaining access to various areas of the fort, and assisting in various aspects of the field work. Rus Allen (Scheduling Branch, Range Division, Fort Hood) and personnel of the Fort Hood Range Control Office coordinated researcher access to colony sites within the live-fire training area. Jeffrey A. Courson, CECER-EN, assisted in territory size analysis. Robin Musson of Fisher, IL, helped in compiling the final report. The USACERL technical editor was Tiffany J. Chapin, Information Management Office.

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1 INTRODUCTION

Background

The U.S. Army is responsible for managing 12.4 million acres of land on 186 major installations worldwide (U.S. Department of the Army [DA] 1989). Many of these lands are used for military training and testing activities, and many are also managed for nonmilitary uses, including fish and wildlife, forest products, recreation, agriculture, and grazing. Proper land management supports the military mission and multiple use activities, but also presents the Army with a unique challenge as a public land steward.

In its effort to promote responsible land stewardship, the Army has initiated the Land Condition-Trend Analysis (LCTA) program, which uses standard methods to collect, analyze, and report natural resources data (Tazik et al. 1992a), and which is the Army's standard for land inventory and monitoring (U.S. Army Engineering and Housing Support Center [USAEHSC] 1990). LCTA is a major component of the Integrated Training Area Management (ITAM) program, both developed at the U.S. Army Construction Engineering Research Laboratories (USACERL). The three other components of ITAM include: (1) Environmental Awareness, (2) Land Rehabilitation and Maintenance, and (3) Training Requirements Integration. LCTA promotes the principles of sustained yield, land stewardship, and multiple use of military land resources. The major objectives of LCTA are to: (1) characterize installation natural resources, (2) implement standards in collection, analysis, and reporting of the acquired data that enable compilation and evaluation of these data Army-wide, (3) monitor changes in land resource condition and evaluate changes in terms of current land uses, (4) evaluate the capability of land to meet the multiple-use demands of the U.S. Army on a sustained basis, (5) delineate the biophysical and regulatory constraints to uses of the land, and (6) develop and refine land management plans to ensure long-term resource availability without compromising the mission.

Such programs help the Army comply with a variety of environmental regulations based on such legislation as the National Environmental Policy Act, the Endangered Species Act, and the Clean Water Act (Donnelly and Van Ness 1986). These regulations require land management personnel at Army installations to take measures to evaluate the impacts of military activities on natural resources, including endangered species, on Army land. The black-capped vireo (*Vireo atricapillus*) was placed on the Federal list of endangered species in October 1987 (52 Federal Register [FR] 37420-37423). The Fort Hood population of the black-capped vireo is one of the most significant within its current range (Tazik et al. 1993a).

The black-capped vireo is a small (10 g) migratory songbird resident on the lands of Fort Hood, Texas each year during the March through August breeding season. Fort Hood initiated a 3-year ecological status survey of the vireo on its lands in 1987 in response to the proposed addition of this species to the Federal list of endangered species (51 FR 44808-44812).

This report is the second in a three-part series documenting the ecology of the black-capped vireo at Fort Hood. Other reports in the series look at distribution and abundance, and population and nesting ecology (Tazik et al. 1993a, Tazik and Cornelius 1993b). A biological assessment of the vireo at Fort Hood (as required by section 7 of the Endangered Species Act [Tazik et al. 1992b]) gathers the data found in these three reports, assesses Army land and species management implications, and makes recommendations based on these findings.

Vireo colony sites are commonly situated in scrub habitat on upland areas that exhibit characteristic geology, soils, elevation, slope, and aspect (Tazik et al. 1993a). Poor soils that hinder tree growth, and fires that set back succession in scrubland areas can provide for good vireo habitat. On Fort Hood, each colony consists of a cluster of 1 to 30 territories—more than 90 percent occupied by monogamous pairs—the remainder held by bachelor males. The species has other Army-land breeding grounds on Fort Sill, OK (Grzybowski and Tazik 1993) and the Camp Bullis Training Site of Fort Sam Houston, TX (Shaw et al. 1989, Rust and Tazik 1990) (Figure 1). The vireo frequents these Army land sites because: (1) Army use prevents urban and agricultural development, and (2) a high fire frequency caused by artillery and flare use promotes the growth of the hardwood scrub habitat it prefers.

As demonstrated by other studies (Tazik et al. 1993a), the Fort Hood population of the black-capped vireo is the largest known under one land management authority. During 1989, an estimated 277 adult vireos occupied territories at colony sites scattered throughout the installation (Figure 2). Although there may be several thousand vireos in existence, this represents about 18 percent of the *known* population in the United States. For this reason too, the Army can play a significant role in eventual recovery of this species. The nearest other major colony sites (civilian) in Texas are located in Travis County near Austin, and Kerr County.

A major threat to the species identified at the time of its endangered species listing was loss of habitat due to grazing, excessive rangeland improvement, natural succession, and urbanization (52 FR 37420-37423). An understanding of the habitat requirements of the vireo on Fort Hood will help the installation's land and wildlife managers identify potential habitat areas (thereby minimizing conflicts with the military mission), and mitigate habitat losses through development of new vireo colony areas and maintenance of existing ones. Results are also expected to have application to the vireo breeding grounds at Fort Sill, OK, and the Camp Bullis Training Site of Fort Sam Houston, TX.

Objective

The objective of this report is to quantitatively assess habitat requirements of the black-capped vireo population at Fort Hood.

Approach

Habitat data were gathered at Fort Hood from within vireo territories as well as adjacent unoccupied habitats during the summer of 1988, toward the end of the breeding season. A variety of univariate and multivariate statistical techniques were used to evaluate the vireo's habitat preferences and to identify management implications.

Mode of Technology Transfer

This research contributes to a fundamental understanding of the ecology of the endangered black-capped vireo, and serves as an example of a proactive approach to endangered species management on Army lands. The information in this and related studies are being transmitted to military and land and wildlife managers at Fort Hood, Headquarters (HQ) U.S. Army Forces Command, and HQ Department of the Army. Data presented here also have been used in preparation of a biological assessment of the vireo on Fort Hood as required by regulations implementing section 7 of the Endangered Species Act (Tazik et al. 1992b). It is anticipated that these data will be updated annually and that a computerized data analysis and reporting program will be developed for timely documentation of annual habitat-monitoring results, as part of the Army's Land Condition-Trend Analysis Program (LCTA).

2 SITE DESCRIPTION

Fort Hood is an 87,890 ha area (U.S. Department of the Army 1989) located in central Texas in Bell and Coryell Counties adjacent to the city of Killeen (Figure 1*). It lies on the eastern fringe of the Edward's Plateau between the cities of Waco (40 miles to the northeast), and Austin (60 miles to the south). The climate is characterized by long, hot summers and short, mild winters. Average monthly temperatures for the Fort Hood area range from a low of about 8 °C in January to a high of 29 °C in July. Average annual precipitation is 81 cm.

The Fort lies entirely within the Lampasas Cutplains physiographic region (Raisz 1952). The forces creating the Balcones Fault Zone, just east of the installation, have displaced underlying rock formations as much as 500 ft. Weathering and erosion over the past 70 million years have produced the present "cutplains" landscape. Soil cover is generally shallow to moderately deep with a high clay content and is supported by limestone bedrock (Nakata 1987).

Elevation ranges from 180 m to 375 m above sea level with 90 percent of the area below 260 m and about 5 percent in bottomlands (Nakata 1987). The landscape exhibits a stairstep topography consisting of a gently rolling to rolling dissected-remnant plateau. Numerous steep sloped hills and ridgelines 40 to 80 m in width rise above the flat to gently rolling plains. This benching is a result of the erosion-resistant limestone cap rocks of the plateau and mesa-hill structures. While the upheld areas exhibit steep slopes, the underlying, less resistant shales and marl show more gradual slopes. Higher elevations occur on the western portions of the Fort and the lowest at the Belton Lake shoreline adjoining the Fort on the east. Surface water drains mostly in an easterly direction.

Fort Hood lies in the Cross Timbers and Prairies vegetation area (Gould 1975), which normally is composed of oak woodlands with a grass undergrowth. Woody vegetation on the installation is derived mostly from the Edward's Plateau vegetational area to the southwest and is dominated by ashe juniper, live oak and Texas oak (scientific names presented in Appendix E). The grasses come from the Blackland Prairie area to the east. Under climax condition these would consist of little bluestem and indiangrass.

Data obtained from the LCTA program at Fort Hood clearly show (Figure 3) that the Fort is divided mainly into perennial grassland (65 percent) and woodland community types (31 percent). Most of the grasslands (83 percent) exhibit a dense or closed vegetative cover. As a result of a long history of grazing and military activity, the Fort's grasslands are dominated by Texas wintergrass (29 percent) and prairie dropseed (18 percent), with little bluestem grasslands comprising only 9 percent of grassland sites (LCTA database).

Broadleaf woodlands comprise about 39 percent of LCTA woodland sites and are dominated mainly by oaks. Coniferous and mixed woodlands comprise 61 percent and are dominated by ashe juniper or a mixture of juniper and various oaks. Additional information can be found in Nakata (1987) and Tazik et al. (1992a).

*The tables and figures begin on page 22.

3 METHODS

Recent studies (Tazik et al. 1992a) have developed methods to locate vireo colony sites and to map vireo territories. Vireo colony sites were located by extensive on-the-ground searching aided by the use of aerial photographs, a helicopter overflight, and valuable information from installation personnel. Individual vireo territories were delineated by following or "driving" males to the boundaries of their territory, and by marking turning points and dispute points with neighbors. Mapping was facilitated by color banding of individual birds to positively identify territory occupants.

Habitat data were collected at seven sites from June through July 1988 using a modified version of the James and Shugart technique (James and Shugart 1970). Sites selected were those to which field personnel could gain access for extended periods of time. Six of these were vireo colony sites. The other was an apparently unoccupied area with vireo-like habitat structure.

Occupied territories (VIREO plots) were selected randomly within each site. An attempt was made to sample these proportionate to the number present. However, at least two territories were sampled at each site, with the exception of the artillery live-fire training area, where fewer than the required number were sampled because of restricted access. Sample sizes at other sites were increased to compensate for this shortfall. An approximately equal number of unoccupied (NONVIREO) plots were also sampled. These were established randomly in areas adjacent to VIREO plots by walking in a random direction from each VIREO plot into the nearest unoccupied area to a distance of approximately 45 m from the territory boundary. In total, 32 VIREO and 30 NONVIREO plots were sampled.

A set of six 0.04 ha circular subplots was randomly located within each plot. All living and dead trees >7.6 cm in diameter at breast height (dbh) within each subplot were counted and classified by species and dbh class (A: >7.6-15.2 cm; B: >15.2-22.9 cm; C: >22.9-38.1 cm; D: >38.1-53.3 cm; E: >53.3-68.6 cm; F: >68.6-83.8 cm; G: >83.8-102 cm; and H: >102 cm). Shrub stems ≤7.6 cm dbh were counted by species within two perpendicular, 20 m long by 1.5 m wide belt transects bisecting the subplots (Figure 4). Percent cover was estimated for each woody plant species by measuring the vertical projection of cover along two 20 m long line transects located along the center line of each belt transect. Vertical vegetation profiles were obtained every 2 m along each line transect, for a total of 20 points per subplot, using a 7.5 m tall, telescoping leveling rod marked off in dm intervals. The number of dm intervals contacting grass, forb (herbaceous plants other than grass), and woody vegetation within each 5 dm interval was recorded. Ground cover was recorded at each of these same points using an ocular with cross hairs held 1 m off the ground, and was classified as bare, rock, litter, grass, woody, and cactus.

4 DATA ANALYSIS

Species composition and habitat structure were compared between VIREO and NONVIREO plots using both univariate and multivariate statistical techniques. The latter included principal component analysis (PCA) and canonical analysis of discriminance (CAD). Species composition was analyzed as percent cover based on the line-transect data. Appendixes B and C list species variables and habitat structure along with variable codes employed in text, tables, and figures.

Univariate Analysis

The t-test was employed to test for differences in the means of habitat structure and species composition variables between classes (i.e., VIREO versus NONVIREO plots). The approximation of the t-test was used whenever the assumption of homogeneity of variances was violated (Sokal and Rohlf 1969). The F-test was used to compare variances between classes for each variable. Fifty habitat structure variables and 29 woody species were included in the univariate analyses (Appendixes B and C). Only those species with mean cover of at least 0.001 percent in either VIREO or NONVIREO plots are reported.

Multivariate Analysis

Only 39 structural variables were included in PCA and CAD. Those variables derived as a summation of other variables were dropped to maximize the ratio of sample size to the number of variables (Krzysik 1987), and to avoid having variables load together in PCA because of a common relationship to another. TREE_HDC, CACT, and TRAC (Appendix C) were ignored because of their small values (Table 1). Juniper cover was included as a structural variable in these analyses because junipers represent a structurally-distinct life form contrasting with hardwoods. Only species that occurred on at least 10 plots were included in multivariate analyses of species composition (Gauch 1982).

Principal Component Analysis

PCA was employed to examine the main sources of variation in the vegetation variables among plots. The effect of PCA is to reduce the extensive data matrix to a smaller number of principal components (PCs) that explain most of the variation in the original habitat variables (Cooley and Lohnes 1971, Green 1979, Pielou 1984, Krzysik 1987). The result is a set of uncorrelated PCs that can be related to sets of the original quantitative variables through correlation analysis. Each PC represents an independent linear combination of the original variables, the ecological interpretation of which is based on the pattern of correlations between it and the original variables. A maximum of four PCs was retained (Krzysik 1987). Varimax rotation was applied to improve the ecological interpretation applicable to each PC (Manley 1986, Krzysik 1987).

PC scores of VIREO and NONVIREO plots were compared using the t-test, and differences were illustrated graphically.

An important assumption of PCA here is that one or more of the resulting PCs represent a gradient among sample sites to which vireos respond. The *a priori* selection of VIREO and NONVIREO plots helped ensure the validity of this assumption. That is, by contributing substantially to the total variance, the between-class variance should be extracted as the primary habitat gradient, PC1, and should be one to which vireos are most likely to respond nonrandomly (Love et al., 1985).

Canonical Analysis of Discriminance

CAD was employed to identify vegetation variables that discriminate between VIREO and NONVIREO plots. It is a dimension reduction technique similar to PCA. However, while PCA summarizes the total variation among the sample plots, CAD derives linear combinations of the original quantitative variables that summarize between-class variation (Tatsuoka 1970, Krzysik 1987, SAS 1988).

Species Diversity

Woody plant species diversity was estimated using Shannon's Index (H′) (Ludwig and Reynolds 1988):

$$H' = -\sum_{i=1}^{S} (p_i \ln p_i) \qquad \text{[Eq 1]}$$

where,

p_i = proportionate abundance of the i^{th} species

S = total number of species

ln = the natural logarithm.

The two components of species diversity–evenness and richness–were evaluated as well. Evenness is a measure of the degree to which woody cover is evenly distributed among the species present. It is highest in a population where all species are equally abundant. Evenness (E′) was calculated as (Ludwig and Reynolds 1988):

$$E' = \frac{H'}{\ln(S)} \qquad \text{[Eq 2]}$$

Species richness is the total count of woody species recorded within each territory. Diversity, evenness, and richness were compared between VIREO and NONVIREO plots using the t-test.

Habitat Correlates of Territory Size

Black-capped vireo territory size and habitat quality may be interrelated. To test for this, a series of bivariate Pearson correlation analyses was performed pairing territory size with each of the 50 habitat-structure variables and the percent cover of the 29 plant species.

Data Transformations

Data were transformed to better meet the assumption of normality, an assumption of the battery of parametric test statistics employed here (Sokal and Rohlf 1969). The arcsine transformation was applied to percent-cover data. Count data, density data, and territory size were transformed using the square-root transformation. Means and confidence limits are reported as the back transformation of the means of the transformed data (Sokal and Rohlf 1969).

All analyses were performed using the *Statistical Analyses System* (SAS) for Personal Computers, Release 6.03 (SAS Institute, Inc.).

5 RESULTS

Univariate Analysis

The results of univariate analyses are presented in Tables 1 and 2. Among the 50 structural variables examined, 12 show significant differences in means between VIREO and NONVIREO plots (Table 1). This is more than expected based on chance alone using the usual significance level of 0.05 (0.05 x 5 = 2.5 expected) indicating the likelihood of real differences in habitat structure between classes. Means for WOCVR_HARD, STEM_HL, STEM, V5 to V25, and VGT30_CV were greater in VIREO plots compared to NONVIREO plots. TREE_JLB, TREE_JLC and GRAS were greater in NONVIREO plots than in VIREO plots.

F-tests revealed a significant difference in the variance between classes in 23 cases. NONVIREO plots had a significantly higher variance in 19 of these, indicating that they tend to be more variable in habitat structure than VIREO plots. The four exceptions involve dead juniper density (see Table 1).

Species composition in VIREO and NONVIREO plots is compared in Table 2. Ten of 29 species differed significantly in mean percent cover, far more than expected by chance alone (0.05 x 29 = 1.45). Flame-leaved sumac, Texas oak, skunkbush sumac, grape, greenbriar, Mexican buckeye, and poison ivy were more abundant in VIREO than in NONVIREO plots. Juniper, live oak, and white honeysuckle were less abundant in VIREO than in NONVIREO plots. Abundance of the 14 most common species found in VIREO plots are also compared in Figure 5. Shin oak, flame-leaved sumac, ashe juniper, Texas oak, skunkbush sumac, redbud, and Texas ash each comprise 1 percent or more of the woody cover in VIREO plots, and together account for 38 percent of the cover. All the remaining species each comprise less than 1 percent cover.

The variance differed significantly between classes in 13 of the 29 species. In most (8 of 13) cases, the variance among VIREO plots was higher than among NONVIREO plots, a trend opposite to that found in the structural habitat variables.

Principal Component Analysis

Habitat Structure

The four PCs retained account for 69.6 percent of the variance in the original habitat structure variables (Table 3). Correlations between these PCs and the original variables are shown in Table 3. PC1 accounts for 22.9 percent of the variance. It represents a gradient of increasing live juniper abundance. PC2 accounts for 21.7 percent and defines a gradient of increasing low hardwood abundance. PC3 accounts for 13.7 percent of the variance and defines a gradient of increasing tall hardwoods and grass ground cover. PC4 accounts for 11.4 percent of the variance. It represents a gradient of increasing dead juniper.

VIREO plots scored significantly lower on PC1 and significantly higher on PC2 compared to NONVIREO plots (Table 4). This indicates avoidance of areas abundant in junipers, and preference for areas with abundant low hardwood vegetation. Results are illustrated in Figure 6. There are no significant differences between classes in mean scores for PC3, or PC4.

F-tests revealed significant departures from homogeneity of variances for PC2 and PC4 scores. PC2 scores were less variable and PC4 scores more variable in VIREO compared to NONVIREO plots. That is, low hardwood abundance was less variable in VIREO, and dead juniper abundance was more variable in VIREO as opposed to NONVIREO plots. The wide scatter of NONVIREO plots along PC2 is apparent in Figure 6.

Plant Species Composition

The results of PCA based on plant species cover are summarized in Table 5. The four PCs retained account for 52.5 percent of the variance in the original variables. PC1 accounts for 17 percent of this, and defines a gradient of increasing abundance of several hardwood species including: Texas oak, skunkbush sumac, poison ivy, Carolina buckthorne, Mexican buckeye, grape, and redbud. PC2 accounts for 14.3 percent of the total variance and represents a gradient of increasing elbowbush, ashe juniper, live oak, and greenbriar, and decreasing flame-leaved sumac. PC3 accounts for 11.5 percent of the variance and defines a gradient of increasing Virginia creeper, deciduous holly, greenbriar, and rusty blackhaw, and decreasing Texas persimmon and evergreen sumac. PC4 accounts for 9.8 percent of the variance and defines a gradient of increasing shin oak, evergreen sumac, and Texas ash, and decreasing netleaf hackberry.

The mean and variance of scores on PC1 were significantly greater on VIREO compared to NONVIREO plots (Table 6). Difference in scores on PC2 were nearly significant (p=0.08) and are plotted with PC1 in Figure 7. PC3 and PC4 scores did not differ between VIREO and NONVIREO classifications (Table 6).

Canonical Analysis of Discriminance

Habitat Structure

CAD of habitat structure data yielded one canonical variable (CAN1) that accounts for 79 percent of the between-class variation (p=0.031). Despite this high level of discriminating power, CAN1, the linear combination of the 39 original variables, misclassified sample sites 38.7 percent of the time; 13 of 32 (40.6 percent) VIREO and 11 of 30 (36.7 percent) NONVIREO plots.

Variables that correlate significantly with CAN1 are shown in Table 7. CAN1 is most strongly and positively correlated with low hardwood cover (WOCVR_HARD, V5 - V25) and stem density (STEM_HL), and negatively correlated with juniper cover (JUAS), live juniper tree density (TREE_JLB, TREE_JLC), and grass cover (GRAS).

Plant Species Composition

CAD using plant species composition data resulted in one canonical variable (CAN1) that accounts for 64.9 percent of the between-class variation at a very high level of significance (p=0.0006). Cross-validation of CAN1, a linear combination of the 22 plant species, yielded an average error rate of 20.8 percent. Eight of 32 (25.0 percent) VIREO plots were misclassified as NONVIREO. Five of 30 (16.7 percent) NONVIREO plots were misclassified as VIREO.

The relationship between CAN1 and the 22 plant species is shown in Table 8. Eight species correlate significantly with CAN1. Species loading positively include flame-leaved sumac, Mexican buckeye, skunkbush sumac, grape, greenbriar, and Texas oak. Species loading negatively include ashe juniper and live oak.

Species Diversity

Mean species diversity and evenness did not differ significantly between VIREO and NONVIREO plots (Table 9). But species richness was significantly higher on VIREO compared to NONVIREO plots. However, the difference (13.5 vs. 11.2 species per plot) does not appear meaningful. Variances differed significantly only in the case of evenness, which was more variable in VIREO than NONVIREO plots.

Territory Size and Habitat Quality

Territory size among the 32 vireo territories included here averaged 4.2 ha (S.E.=0.386, n=32). Among the 50 structural variables, only V30 was correlated with territory size ($r=-0.395$, $p=0.025$). The only plant species correlated with territory size was skunkbush sumac ($r=-0.354$, $p=0.047$). These two correlations are about half the number expected due to chance alone ([50+29] x 0.05=3.95).

6 DISCUSSION

Habitat of the black-capped vireo is heterogeneous scrub, characterized by a patchy distribution of shrub clumps and thickets with a few scattered trees and abundant hardwood foliage to ground level. Graber (1961) described it as "wooly." Such habitat often results from fire in otherwise mature juniper-oak stands or edaphic conditions that retard woody plant growth. The best vireo habitats found by Marshall and coworkers were in 10 to 15 year-old burns that were hot enough to kill junipers (Marshall et al. 1985). Similarly, vireo habitat on Fort Hood appears to have resulted from recent fires--most, if not all, the result of artillery and stray flares employed during military training activities. Vireo habitat on Fort Hood was found (Tazik et al. 1993a) to develop within 5 years after fire in otherwise mature oak-juniper woodland, and remains acceptable to the vireo another 20 to 25 years before natural succession leads to undesirable habitat conditions.

Univariate Analysis

Black-capped vireos on Fort Hood preferred areas with abundant low hardwood vegetation over areas dominated by juniper and live oak (Tables 1 and 2). This corresponds to what is generally known about black-capped vireo habitat. Grzybowski (1986) also reported a paucity of junipers in vireo territories relative to unoccupied areas in Texas and Oklahoma.

Species composition clearly differed between VIREO and NONVIREO plots (Table 2). However, the occurrence or lack of statistical significance for a given species is not a direct reflection of the importance of that species to the vireo. For example, although shin oak did not differ in abundance between classes, it is nevertheless an important and consistent component of vireo habitat on Fort Hood. It was the most common species recorded on VIREO plots and was the species most commonly used as a nest substrate (28.1 percent of 249 nests observed; Fort Hood field data). In contrast, flame-leaved sumac was more common in VIREO plots compared to NONVIREO plots, but was seldom used for nesting (7.6 percent). The importance of these species as foraging substrate and escape cover has not yet been reported.

NONVIREO plots exhibited greater variability than VIREO plots in many of the structural variables (Table 1). This resulted from the fact that the NONVIREO plots sampled represented a broader range of habitat types compared to the VIREO plots sampled. NONVIREO plots were located in successional stages both earlier and later than stages occupied by vireos. The opposite trend--greater variance among VIREO plots--was observed only in the case of dead juniper trees (further discussion below).

Greater variability for structural variables in NONVIREO compared to VIREO plots is not explained by a correlation between the means and the variances. In 11 of the 23 cases of nonhomogeneity of variances, means and variances differed between classes in the same direction, while 12 differed in the opposite direction (Table 2). Therefore, a significantly higher variance in one class compared to the other was accompanied by a higher mean about half the time--the result expected based on chance alone. Note that the means themselves did not necessarily differ significantly between classes, only the direction of the difference is considered.

In contrast, percent cover of individual plant species tended to be more variable among VIREO plots than among NONVIREO plots. This suggests that requirements for a particular species composition within vireo territories may be less stringent than requirements for habitat structure. However, here the means and the variances of species cover do covary. In all cases of nonhomogeneity of variances, the direction of the difference between classes was the same for both the mean and the variance. That is, higher variance for a species was accompanied by higher mean cover. Therefore, it is not clear whether VIREO plots are more variable in species cover, or whether the result is an artifact of the higher means for several hardwood species within VIREO plots.

Principal Component Analysis

Habitat Structure

The four major habitat gradients detected by PCA were: PC1, live juniper abundance; PC2, low hardwood abundance; PC3, tall hardwood abundance; and PC4, dead juniper abundance. Only PC1 and PC2 differed between classes. VIREO plots scored higher on PC1 and lower on PC2 compared to NONVIREO plots (Table 4 and Figure 6). This indicates (in conformance with univariate analysis) that black-capped vireos prefer habitats with abundant low hardwood vegetation, and low density and cover of live junipers. Tall hardwood vegetation and grass ground cover (PC3), and density of dead juniper stems and trees (PC4), appear to be less important factors in vireo habitat selection at Fort Hood.

The higher variance among NONVIREO plots compared to VIREO plots observed on PC2, and near significance on PC1 ($p=0.08$), are similar to the results of the univariate analyses, and can be attributed to the wider range of habitats sampled by NONVIREO plots. This is illustrated by the four NONVIREO points in the lower left of Figure 6 which represent sample sites in an area where vegetation was scraped by bulldozers several years previously. This area was in a pre-vireo successional stage at the time of sampling, and contrasts sharply with those NONVIREO sample sites scoring high on both PC1 and PC2 that were in a post-vireo successional stage (i.e., mature juniper-oak stands).

Contributing to the trend towards higher variance among NONVIREO plots along PC1 were the four NONVIREO points in the lower right of Figure 6 located within a group of VIREO points. These represent samples obtained in an area that was later colonized by the vireo. No vireos were observed in this area prior to initiation of vegetation sampling in early June despite several visits to the site. Vireos were observed in the vicinity of the NONVIREO sample plots during July in the course of vegetation sampling, as well as during the 1989 breeding season.

The greater variation among VIREO compared to NONVIREO plots along PC4 (dead juniper abundance) is in agreement with results of the univariate analyses (Table 1). Dead junipers are the remnants of fires in oak-juniper habitat on the Fort, and are conspicuous in young vireo colony sites. The snags are often used as singing perches by male vireos, but apparently are not a critical habitat component as the loss of these snags over time does not diminish the viability of a colony site.

Plant Species Composition

Of the four PCs derived from the PCA based on plant species composition, the first two were the easiest to interpret. Species loading heavily on PC1 were largely those that were more common in VIREO, as compared to NONVIREO plots (e.g., Texas oak, skunkbush sumac, poison ivy, Mexican buckeye, and grape). VIREO plots scored higher than NONVIREO plots on PC1 (Table 6) indicating a positive response to this group of species, in keeping with the results of the univariate analyses. Species loading positively on PC2 included two that were less abundant in VIREO than in NONVIREO plots (i.e., ashe juniper and live oak). Flame-leaved sumac loaded negatively on PC2 and was more abundant in VIREO plots. Although not statistically significant ($p=0.08$), VIREO plots tended to score lower on PC2 than NONVIREO plots, consistent with results of the univariate analysis.

VIREO plots were more variable along PC1 than NONVIREO plots, indicating that the linear combination of the several hardwood species' abundance represented by this PC vary more substantially among VIREO plots than among NONVIREO plots. This suggests that the requirements for a particular hardwood species composition within vireo territories may be less stringent than requirements for the abundance of low hardwood cover, which, as noted above, was less variable in VIREO than in NONVIREO plots. This flexibility with regard to species composition is not surprising given that the vireo encounters a wide array of hardwood species throughout its range (Grzybowski 1986; Grzybowski et al. 1990).

Canonical Analysis of Discriminance

CAD was employed to identify those habitat and vegetation variables that distinguish VIREO and NONVIREO plots. In the case of both structural variables and species composition, results paralleled those of the respective univariate analyses. A comparison of Tables 1 and 2 to Tables 7 and 8 shows that most variables significant in univariate comparisons also loaded heavily on CAN1 in each case.

VIREO and NONVIREO plots were distinguished on the basis of both habitat structure and composition of woody species. CAD based on the structural variables had higher discriminatory power but less predictive capability than CAD based on plant species composition. The structural CAD accounted for 79 percent of the between-class variance while composition CAD accounted for 64.9 percent. However, structural CAN1 misclassified 38.7 percent of the plots, while composition CAN1 misclassified 20.8 percent of the plots.

Some misclassification of plots was expected for three reasons (see also Grzybowski 1986). First, NONVIREO plots might not be unsuitable due to habitat but could still be unoccupied if the vireo population is limited by nonhabitat-related factors. (Cowbird parasitism, for example, has severely limited vireo reproductive success throughout its range (Marshall et al. 1985, Grzybowski 1989) including Fort Hood (Tazik and Cornelius 1993b). The four NONVIREO plots in the lower right of Figure 6 are a case in point. Although unoccupied prior to early June 1988, habitat in the vicinity of those plots was occupied late in the season during 1988 and again throughout the 1989 breeding season. Second, vireos may establish territories in marginal areas adjacent to preferred habitat that is occupied by several other vireos. Such marginal habitats might normally be unoccupied if isolated from preferred habitat patches. Figure 7 shows a good example of this. The plot scoring highest on PC1 (live juniper abundance) is a VIREO plot. This vireo territory was on the margin of a vireo colony site that included ten other territories. It had an abundant cover of ashe juniper unlike most other VIREO plots. Finally, all the habitat within an occupied territory may not be equally suitable or equally used. Sampling of unsuitable habitat within the territory increases the likelihood of misclassification.

Species Diversity

VIREO and NONVIREO plots were similar in woody-plant species diversity and evenness (Table 9). The difference in richness between classes, although statistically significant, did not appear to be substantial. The higher variability in the evenness component in VIREO compared to NONVIREO plots suggests that the degree to which certain plant species tend to dominate the habitat varied more among VIREO than NONVIREO plots. This may be related to the finding that species composition tended to be more variable in VIREO rather than NONVIREO habitats. Again, this is in contrast to habitat structure, which was less variable in VIREO than NONVIREO plots.

Territory Size and Habitat Quality

Black-capped vireo territory quality, as reflected in habitat structure and species composition, was unrelated to territory size. This result was unanticipated. Given the vireo's preference for abundant low-hardwood cover and minimal juniper cover, it was expected that territory size would increase with juniper abundance and decrease with increasing low-hardwood cover. Conner and coworkers (Conner et al. 1986), for example, observed negative correlations between territory size of the northern cardinal and both foliage density under 3 m and shrub density–and a positive correlation with vegetation height in an east Texas study area. Factors other than the habitat variables examined here appear to influence vireo territory size on Fort Hood.

If territory size is established as a balance between the tendency for population pressure to reduce it and requirements for efficient foraging and sufficient nesting habitat to increase it, then the lack of

significant population pressure may permit individual territory occupants to range over a substantially larger area than necessary to meet minimum requirements for food and cover. The population of an endangered species, such as the vireo, whose reproductive success is limited by cowbird parasitism (Tazik and Cornelius 1993b), might be sufficiently low to permit such a situation. Thus, the lack of meaningful correlations between vireo territory size and habitat quality on Fort Hood may be the result of subnormal population densities that permit vireo territory size to be independent of habitat quality.

Habitat Use

Preference for abundant low hardwood vegetation is related, at least in part, to vireo nesting habits. Average nest height among Fort Hood vireos was 108.4 cm (S.E.=2.656, n=250; unpublished data). Over 95 percent of all nests observed were in the range of 50 to 200 cm–within the zone of maximum vegetation volume on VIREO plots (i.e., V5, V10, and V15 in Table 1). Graber (1961) and Grzybowski (1986) also noted a relationship between nesting requirements and abundant low hardwood vegetation. Vireos also were observed to forage extensively in low hardwood vegetation, but substrate preferences and foraging height have not been quantified.

7 SUMMARY

1. The black-capped vireo prefers habitats with an abundant layer of low hardwood vegetation under 3 m, and a low density of ashe juniper trees. Low hardwood vegetation is required for nesting and also appears to be used extensively for foraging. Loss of this hardwood cover through habitat destruction, natural succession, or juniper invasion will have a negative impact on the vireo.

2. Composition of the hardwood cover in vireo territories is important but varies from site to site. Shin oak is an important constituent of vireo habitat on Fort Hood but is usually accompanied by a diversity of other hardwood species. Habitat structure appears to be more critical in determining the suitability of the habitat for the vireo than either species composition or diversity.

3. Vireo habitat at Fort Hood may not be fully occupied in any given year. Vireo territory size at Fort Hood was unrelated to any of the habitat variables examined, suggesting that population density on the Fort may be below carrying capacity.

4. The combination of univariate and multivariate statistical techniques employed in the habitat analysis provided useful insight into habitat requirements of the vireo on Fort Hood. Principal components analysis was an effective analytical tool for quantifying vireo habitat preferences. Canonical analysis of discriminance (CAD) and the univariate analyses produced similar results. However, CAD also permitted quantification of the degree of discrimination between VIREO and NONVIREO plots using habitat structure and species composition data. Further multivariate analyses of these data will include combining key structual and species composition variables to improve discrimination and predictive capabilities.

5. Fire can be both beneficial and destructive to vireo habitat. Accidental fires resulting from artillery and stray flares have created abundant habitat on Fort Hood and should not be discouraged. On the other hand, fires set by installation and contract personnel for juniper control should be coordinated with endangered species management personnel at the Fort Hood Environmental Management Office to avoid inadvertent habitat destruction and possible fines or litigation.

6. Black-capped vireo habitat on Fort Hood, as elsewhere, is ephemeral. Habitat typically develops within about 5 years after fire in otherwise mature oak-juniper woodland, and remains suitable another 20 to 25 years. Keeping close track of colony sites of known age will allow prediction of future habitat availability and potential vireo numbers, and establishes a basis for long-term habitat maintenance planning.

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APPENDIX A:

Tables and Figures

Table 1

Means and 95 Percent Confidence Limits of Habitat Structure Variables for VIREO and NONVIREO Plots and the Results of F and t Tests

	VIREO Plots			NONVIREO Plots			F test	t test
Variable[a]	Mean	LL	UL	Mean	LL	UL	p	p
WOCVR	51.12	47.51	54.73	43.08	35.50	50.83	0.000***	0.062
WOCVR_CV	28.98	25.46	32.50	36.68	29.30	44.07	0.000***	0.061
WOCVR_HARD	45.47	41.57	49.39	30.73	25.09	36.68	0.018*	0.000***
STEM	1772.9	1602.89	1951.54	1036.30	794.67	1309.97	0.001***	0.000***
STEM_CV	32.51	28.38	36.65	42.41	29.35	55.46	0.000***	0.149
STEM_JL	99.7	56.21	155.60	167.80	95.89	259.53	0.259	0.135
STEM_JD	39.9	20.82	65.00	42.20	22.67	67.71	0.828	0.881
STEM_HL	1474.9	1302.87	1657.64	675.10	489.87	889.89	0.010**	0.000***
STEM_HD	67.3	45.83	92.74	56.90	38.07	79.38	0.682	0.500
STEM_DD	129.6	99.05	164.13	106.90	70.65	150.49	0.146	0.374
TREE	27.4	18.74	37.55	37.30	24.52	52.77	0.228	0.221
TREE_CV	96.45	75.38	117.52	70.50	47.80	93.20	0.815	0.092
TREE_JL	7.8	4.46	11.96	14.20	8.33	21.45	0.188	0.074
TREE_JD	3.8	1.31	7.45	1.60	0.59	2.85	(0.001)***	0.121
TREE_HL	7.4	4.06	11.56	14.20	8.39	21.54	0.243	0.055
TREE_HD	2.9	1.84	4.28	3.90	2.27	5.97	0.160	0.359
TREE_DD	8.0	4.37	12.54	5.90	3.46	8.90	0.109	0.387
TREE_JLA	5.6	2.98	9.00	8.70	4.93	13.39	0.565	0.225
TREE_JLB	1.3	0.70	2.02	3.90	2.21	5.91	0.003**	0.004**
TREE_JLC	0.6	0.26	0.98	1.50	0.78	2.29	0.027*	0.028*
TREE_JDA	2.6	0.91	4.98	0.80	0.24	1.57	(0.000)***	0.059
TREE_JDB	1.0	0.35	1.89	0.60	0.21	1.01	(0.007)**	0.278
TREE_JDC	0.6	0.15	1.16	0.30	0.04	0.53	(0.002)**	0.219
TREE_HLA	6.0	3.41	9.36	11.50	6.77	17.34	0.192	0.058
TREE_HLB	1.0	0.32	1.93	2.20	1.03	3.66	0.352	0.112
TREE_HLC	0.2	0.05	0.42	0.30	0.06	0.64	0.059	0.545
TREE_HDA	2.7	1.68	3.93	3.50	2.10	5.16	0.369	0.397
TREE_HDB	0.2	0.01	0.42	0.40	0.07	0.91	0.004**	0.276
TREE_HDC	0.0	0.00	0.00	0.00	0.00	0.00		
V5	111.0	102.96	119.40	91.1	85.06	97.37	0.231	0.000***
V10	149.3	138.98	159.91	113.0	96.64	130.55	0.002**	0.001***
V15	124.7	116.50	133.10	83.2	65.55	102.99	0.000***	0.001***
V20	96.1	87.52	105.04	61.9	45.24	81.17	0.000***	0.003**
V25	67.7	57.53	78.65	46.9	33.42	62.64	0.011*	0.028*
V30	44.1	34.98	54.37	38.3	25.89	53.10	0.042 *	0.484
V40	39.1	27.43	52.77	45.0	28.59	65.15	0.151	0.580
V50	15.9	9.39	24.09	24.8	13.92	38.60	0.142	0.194
V60	5.5	2.69	9.09	11.3	5.71	18.56	0.078	0.080
V70	1.9	0.65	3.60	4.1	1.63	7.51	0.075	0.146
V70+	0.7	0.13	1.42	2.5	0.50	5.65	0.000***	0.103
VLT30_CV	23.11	19.74	26.48	26.68	21.60	31.76	0.041*	0.237
VGT30_CV	104.54	88.89	120.19	74.37	53.09	95.65	0.135	0.022*
VGRAS	46.6	35.17	59.59	58.0	44.19	73.76	0.783	0.224
VFORB	37.7	30.64	45.52	30.4	18.32	45.46	0.000***	[illegible]
WOOD	66.39	62.49	70.18	61.24	53.98	68.26	0.003**	0.200
GRAS	24.80	18.66	31.51	34.81	28.37	41.54	0.568	0.032*
FORB	16.72	13.21	20.56	14.93	8.52	22.75	0.000***	0.656
ROCK	11.26	8.06	14.92	8.59	5.41	12.43	0.542	0.275
CACT	0.11	0.01	0.31	0.22	0.07	0.46	0.535	0.366
TRAC	0.36	0.04	1.01	0.40	0.03	1.15	0.748	0.921

[a]For F values, the variance was higher among NONVIREO plots unless p is enclosed in parentheses. Symbols: *$0.01 < p \le 0.05$, **$0.001 < p \le 0.01$, ***$p \le 0.001$; Variable code descriptions in Appendix C.

Table 2

Means and 95 Percent Confidence Limits of Woody Plant Cover by Species for VIREO and NONVIREO Plots and the Results of F and t Tests

	VIREO Plots[a]			NONVIREO Plots			F test	t test
Species	**Mean**	**LL**	**UL**	**Mean**	**LL**	**UL**	**p**	**p**
Shin Oak	17.45	13.18	22.18	14.24	9.93	19.18	0.668	0.316
Flame-leaved Sumac	7.94	3.90	13.25	1.03	0.29	2.24	(0.001)***	0.000***
Ashe Juniper	5.17	2.92	8.02	12.24	7.05	18.60	0.033*	0.017*
Texas Oak	3.16	1.12	6.18	0.63	0.18	1.35	(0.000)***	0.017*
Skunkbush Sumac	1.58	0.91	2.42	0.47	0.18	0.90	0.316	0.005**
Red Bud	1.19	0.64	1.90	1.04	0.51	1.77	0.859	0.742
Texas Ash	1.07	0.45	1.96	1.92	0.69	3.75	0.036*	0.285
Grape	0.76	0.44	1.18	0.20	0.05	0.47	0.816	0.008**
Elbow Bush	0.65	0.24	1.23	0.93	0.46	1.57	0.593	0.444
Greenbriar	0.62	0.33	0.98	0.19	0.07	0.38	0.359	0.012*
Live Oak	0.35	0.13	0.66	1.09	0.44	2.01	0.007**	0.039*
Mexican Buckeye	0.34	0.11	0.69	0.02	0.00	0.09	(0.002)**	0.003**
Texas Persimmon	0.13	0.04	0.27	0.05	0.00	0.15	0.775	0.230
Poison Ivy	0.12	0.05	0.21	0.03	0.01	0.08	0.373	0.040
Netleaf Hackberry	0.05	0.01	0.14	0.08	0.02	0.20	0.941	0.507
Rusty Blackhaw	0.05	0.01	0.13	0.07	0.00	0.23	0.097	0.664
Gum Bumelia	0.10	0.03	0.19	0.07	0.02	0.16	0.929	0.642
Evergreen Sumac	0.06	0.00	0.22	0.04	0.00	0.13	0.096	0.669
Carolina Buckthorne	0.06	0.01	0.14	0.01	0.00	0.03	(0.031)*	0.062
False Willow	0.02	0.00	0.10	0.00	0.00	0.02	(0.000)***	0.272
Deciduous Holly	0.02	0.00	0.07	0.01	0.00	0.04	0.456	0.443
Cedar Elm	0.01	0.00	0.07	0.03	0.00	0.09	0.618	0.613
Mountain Laurel	0.01	0.00	0.03	0.00	0.00	0.00	(0.000)***	0.083
Eve's Necklace	0.01	0.00	0.03	0.00	0.00	0.01	(0.005)*	0.326
Virginia Creeper	0.01	0.00	0.02	0.00	0.00	0.01	(0.021)*	0.126
Mexican Plum	0.00	0.00	0.02	0.01	0.00	0.04	0.060***	0.657
Post Oak	0.00	0.00	0.01	0.11	0.01	0.62	0.000***	0.171
Blackjack Oak	0.00	0.00	0.00	0.09	0.00	0.36		0.055
White Honeysuckle	0.00	0.00	0.00	0.02	0.00	0.05	0.000***	0.026*

[a] For F values, the variance was higher among NONVIREO plots unless the p value is enclosed in parentheses; Symbols as in Table 1.

Table 3

Eigenvalues, Proportion and Cumulative Proportions of Variance Accounted for by the First Four Principal Components, and Pearson Correlations Between Each PC and the Original Habitat Structure Variables

Components[a]	PC1	PC2	PC3	PC4
Eigenvalues	8.9412	8.4515	5.3288	4.4291
Proportion of Variance	0.2293	0.2167	0.1366	0.1136
Cumulative Proportion	0.2293	0.4460	0.5826	0.6962
WOCVR		-0.753***		
JUAS	0.947***			
WOOD_HARD		0.889***		
STEM_JL	0.873***			
STEM_JD	0.474***			0.660***
STEM_HL	-0.325**	0.850***		
STEM_HD	0.389**	0.498***	0.290*	-0.408***
STEM_CV		-0.724***		
TREE_JLA	0.852***			
TREE_JLB	0.762***		0.289*	
TREE_JLC	0.625***		0.337**	0.267*
TREE_JDA				0.923***
TREE_JDB				0.890***
TREE_JDC				0.895***
TREE_HLA	0.680***		0.481***	
TREE_HLB	0.396**		0.709***	
TREE_HLC			0.601***	
TREE_HDA		0.287*	0.532***	
TREE_HDB			0.502***	
TREE_CV	-0.533***	0.316**		
WOOD	0.282*	0.847***		
FORB	-0.558***	-0.528**	-0.262*	0.393**
GRAS		-0.306*	0.724**	
ROCK			-0.763***	
V5	-0.276*	0.463***	-0.263*	-0.332**
V10	-0.276*	0.860***		
V15		0.935***		
V20	0.258*	0.859***		
V25	0.547***	0.688***		0.306*
V30	0.721***	0.492***		0.250*
V40	0.809***	0.281*	0.301*	
V50	0.721***		0.513***	
V60	0.596***		0.666***	
V70	0.490***		0.611***	0.259*
V70+	0.402**		0.499***	
VLT30_CV	-0.277*	-0.560***		
VGT30_CV	-0.370**	0.477***		
VGRAS		-0.255*	0.748***	
VFORB	-0.602***	-0.452***	0.748***	0.447***

[a]Symbols as in Table 1. Variable code descriptions in Appendix C.

Table 4

Means and Standard Errors (SE) of Principal Component Scores Based on Habitat Structure Variables for VIREO and NONVIREO Plots and F and t Tests

		VIREO[a]	NONVIREO	F test	t test
PC	Descriptor	Mean (SE)	Mean (SE)	p	p
1	Live Junipers	-0.266 (0.1429)	0.284 (0.2036)	0.081	0.029*
2	Low Hardwoods	0.426 (0.0838)	-0.454 (0.2199)	0.000***	0.001***
3	Tall Hardwoods	-0.179 (0.1644)	0.190 (0.1920)	0.503	0.148
4	Dead Juniper	0.128 (0.2140)	-0.136 (0.1291)	0.005**	0.296

[a] Symbols as in Table 1.

Table 5

Eigenvalues, Proportion and Cumulative Proportion of Variance Accounted for by the First Four Principal Components, and Pearson Correlations Between Each PC and the Original Plant Species Cover Variables

	PC1[a]	PC2	PC3	PC4
Eigenvalue	3.7411	3.1347	2.5230	2.1569
Proportion of Variance	0.1700	0.1425	0.1147	0.0980
Cumulative Variance	0.1700	0.3125	0.4272	0.5253
Shin Oak				0.789***
Flame-leaved Sumac		0.815***		
Ashe Juniper		0.666***		
Texas Oak	0.752***			
Skunkbush Sumac	0.728***			0.394**
Redbud	0.477***			
Texas Ash				
Grape	0.617***			0.530***
Elbowbush		0.818***		-0.347**
Greenbriar		0.430***	0.606***	
Live Oak	-0.360**	0.507***		
Mexican Buckeye	0.632***			
Texas Persimmon	0.388**		-0.459***	
Poison Ivy	0.714***			
Netleaf Hackberry		0.677***		-0.413***
Rusty Blackhaw			0.544***	
Gum Bumelia	0.397**			-0.397***
Evergreen Sumac			-0.439***	0.603***
Carolina Buckthorne	0.671***			
Deciduous Holly			0.607***	
Cedar Elm				
Virginia Creeper			0.653***	

[a] Symbols as in Table 1.

Table 6

Means and Standard Errors (SE) of Principal Component Scores Based on Plant Species Cover Between VIREO and NONVIREO Plots and F and t Tests

	VIREO Plots[a]	NONVIREO Plots	F test	t test
PC	Mean (SE)	Mean (SE)	p	p
1	0.398 (0.1925)	-0.424 (0.1258)	0.015*	0.001***
2	-0.214 (0.1758)	0.229 (0.1771)	0.895	0.081
3	0.139 (0.1683)	-0.148 (0.1907)	0.611	0.263*
4	0.076 (0.1609)	-0.081 (0.2004)	0.309	0.542

[a] Symbols as in Table 1.

Table 7

Pearson Correlations (r) Between the Canonical Variate and the Original Habitat Structure Variables

Variable[a]	r	Variable	r
Woody cover		Vertical Hits	
WOCVR_CV	-0.276*	V5	0.513***
JUAS	-0.345**	V10	0.479***
WOCVR_HARD	0.541***	V15	0.508***
Stems		V20	0.441***
STEM_CV		V25	0.319**
STEM_JL		V30	
STEM_JD		V40	
STEM_HL	0.669***	V50	
STEM_HD		V60	-0.252*
Trees		V70	
TREE_CV		V70+	
TREE_JLA		VLT30_CV	
TREE_JLB	-0.412***	VGT30_CV	0.327**
TREE_JLC	-0.320*	VGRAS	
TREE_JDA	0.268*	VFORB	
TREE_JDB		Ground Cover	
TREE_JDC			
TREE_HLA	-0.272	WOOD	
TREE_HLB		GRAS	-0.306*
TREE_HLC		FORB	
TREE_HDA		ROCK	
TREE_HDB			
TREE_HDC			

[a]Symbols as in Table 1. Variable descriptions in Appendix C.

Table 8

Pearson Correlations Between the Canonical Variate (CAN1) and the Original Plant Species Cover Variables

Species[a]	CAN1
Shin Oak	
Flame-leaved Sumac	0.536***
Ashe Juniper	-0.381**
Texas Oak	0.372**
Skunkbush Sumac	0.435***
Redbud	
Texas Ash	
Grape	0.415***
Elbowbush	
Greenbriar	0.392**
Live Oak	-0.332**
Mexican Buckeye	0.452**
Texas Persimmon	
Poison Ivy	
Netleaf Hackberry	
Rusty Blackhaw	
Gum Bumelia	
Evergreen Sumac	
Carolina Buckthorne	
Deciduous Holly	
Cedar Elm	
Virginia Creeper	

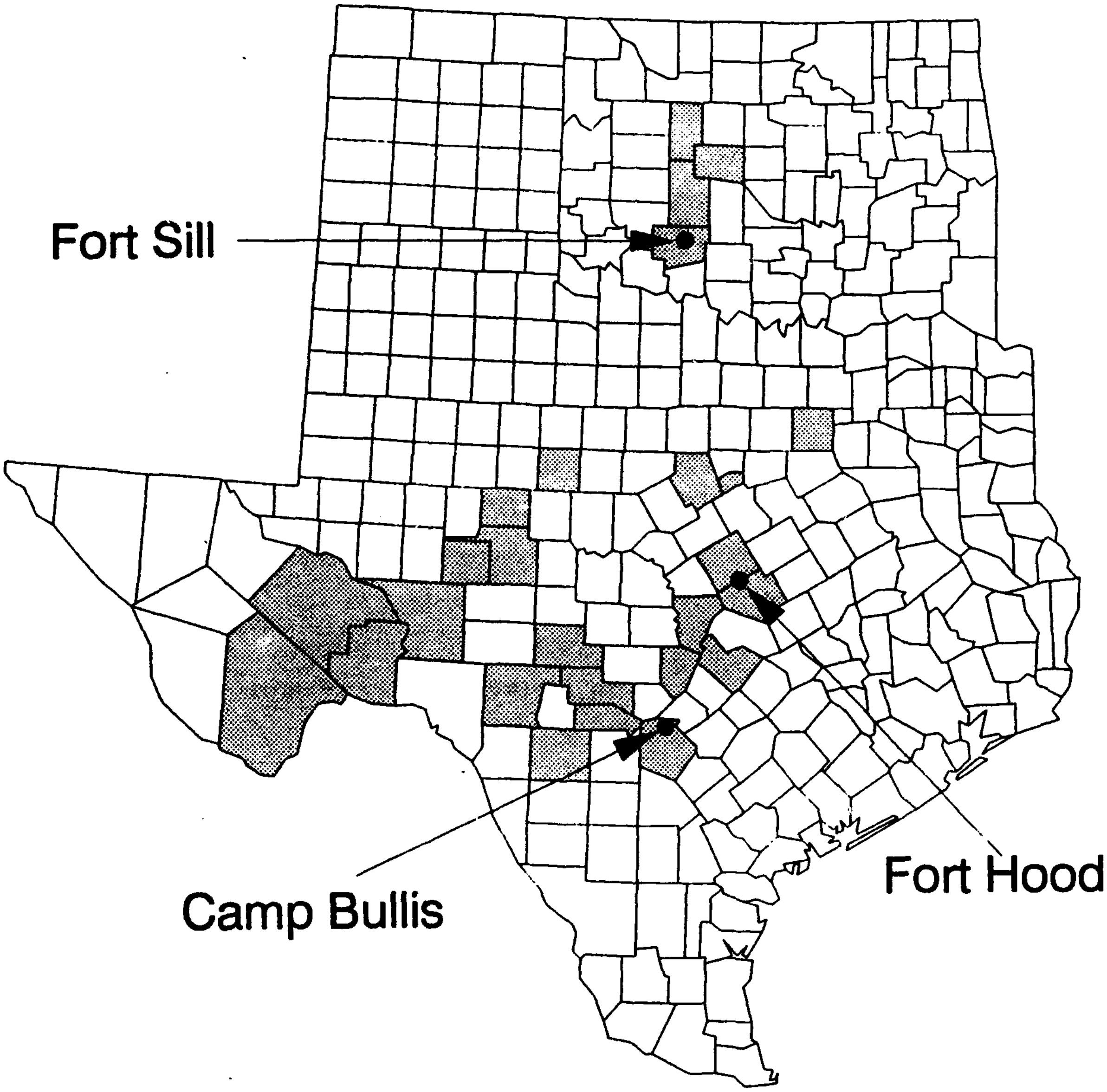
[a]Symbols as in Table 1.

Table 9

Means and Standard Errors (SE) of Woody Plant Species Diversity, Evenness, and Richness on VIREO and NONVIREO Plots and Results of F and t Tests

	VIREO Plots	NONVIREO Plots	F test	t test
Variable	Mean SE	Mean SE	p	p
Diversity	1.612 (0.06576)	1.493 (0.05024)	0.106	0.156
Evenness	0.622 (0.02021)	0.639 (0.01343)	0.019*	0.467
Richness	13.469 (0.53879)	11.200 (0.67022)	0.311	0.011*

[a]Symbols as in Table 1.



Note: Modified from Marshall et al. 1985.

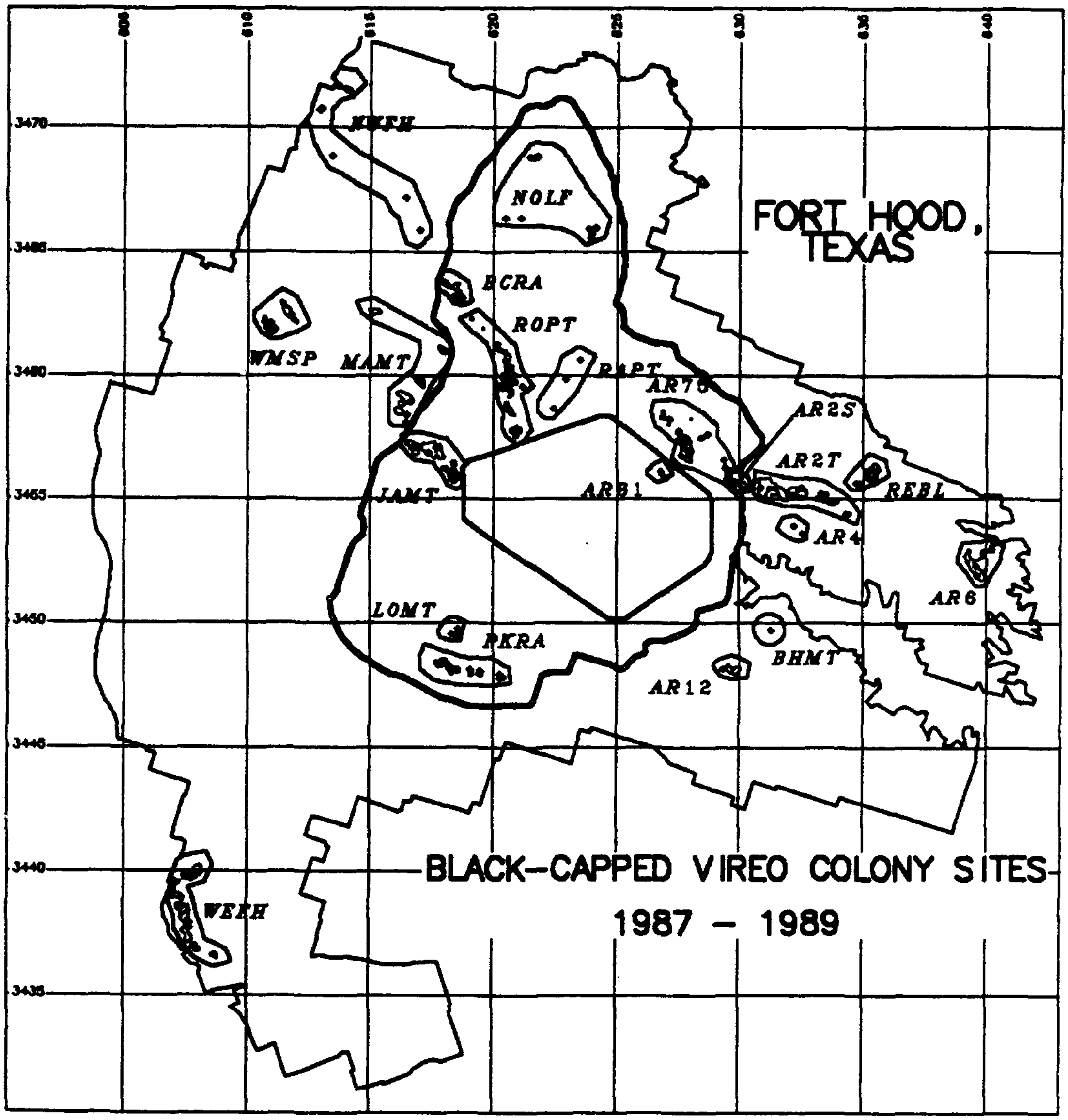
Figure 1. Current Distribution of the Black-capped Vireo in Texas and Oklahoma by County.

LOCATION: hood DATE: Fri Aug 17 10:23:10 1990
MAPSET: grass USER: grass

CELLFILE: none
MASK: <border> in mapset <PERMANENT>

Produced by: US Army CERL, Champaign Illinois
Software: GRASS

LOCATION: Fort Hood, Texas



SCALE: 1 : 199034

WINDOW: 600300.00 3474750.00 643000.00 3430250.00 (grid: 5000 meters)

border (PERMANENT)

live.fire.zone (grass)

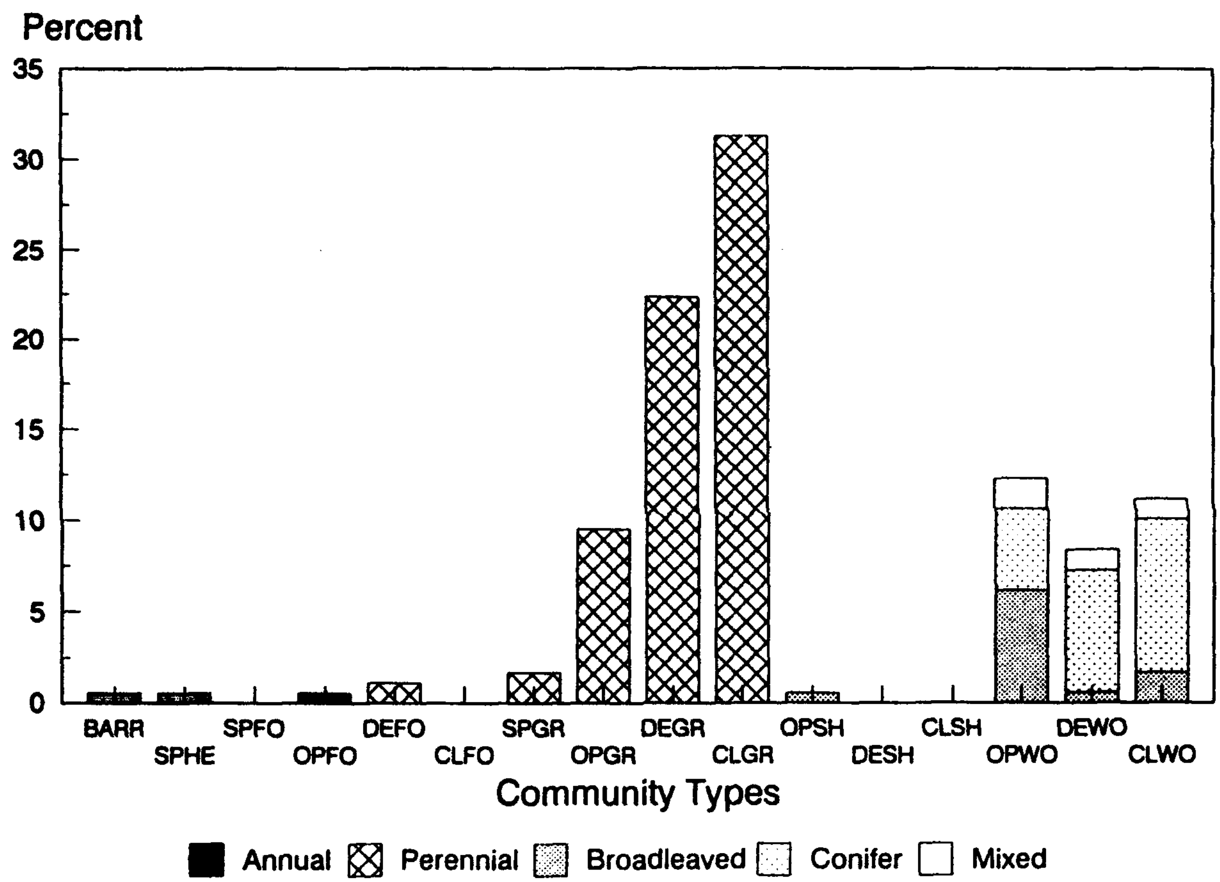
impact (PERMANENT)

vireo.all (grass)

vireo.areas (grass)

Note: See Appendix D for code descriptions.

Figure 2. Black-capped Vireo Colony Sites on Fort Hood (Grid: 5000 m).



Note: See Appendix E for explanation of Community types.

Figure 3. Fort Hood Plant Community Types.

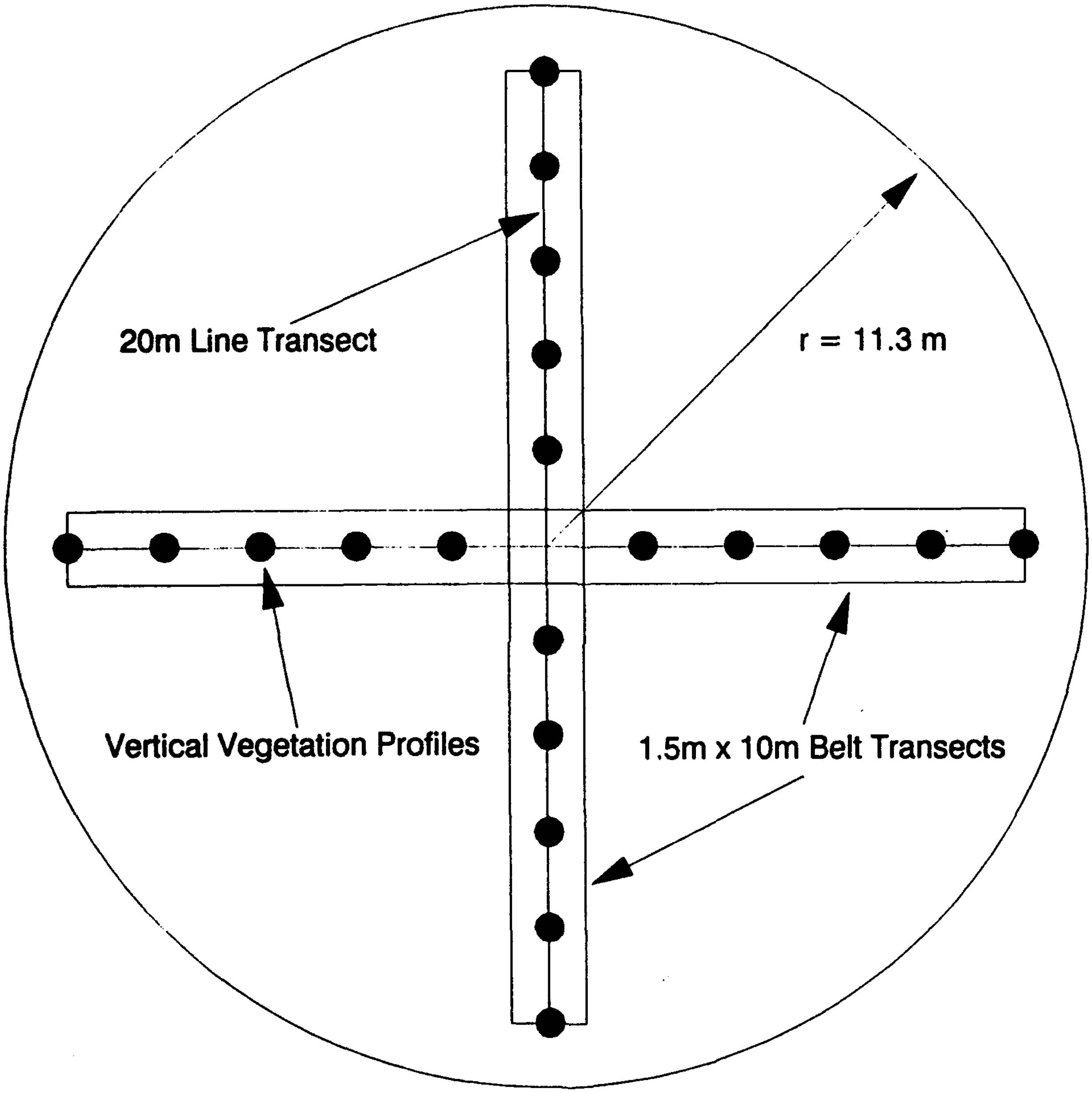
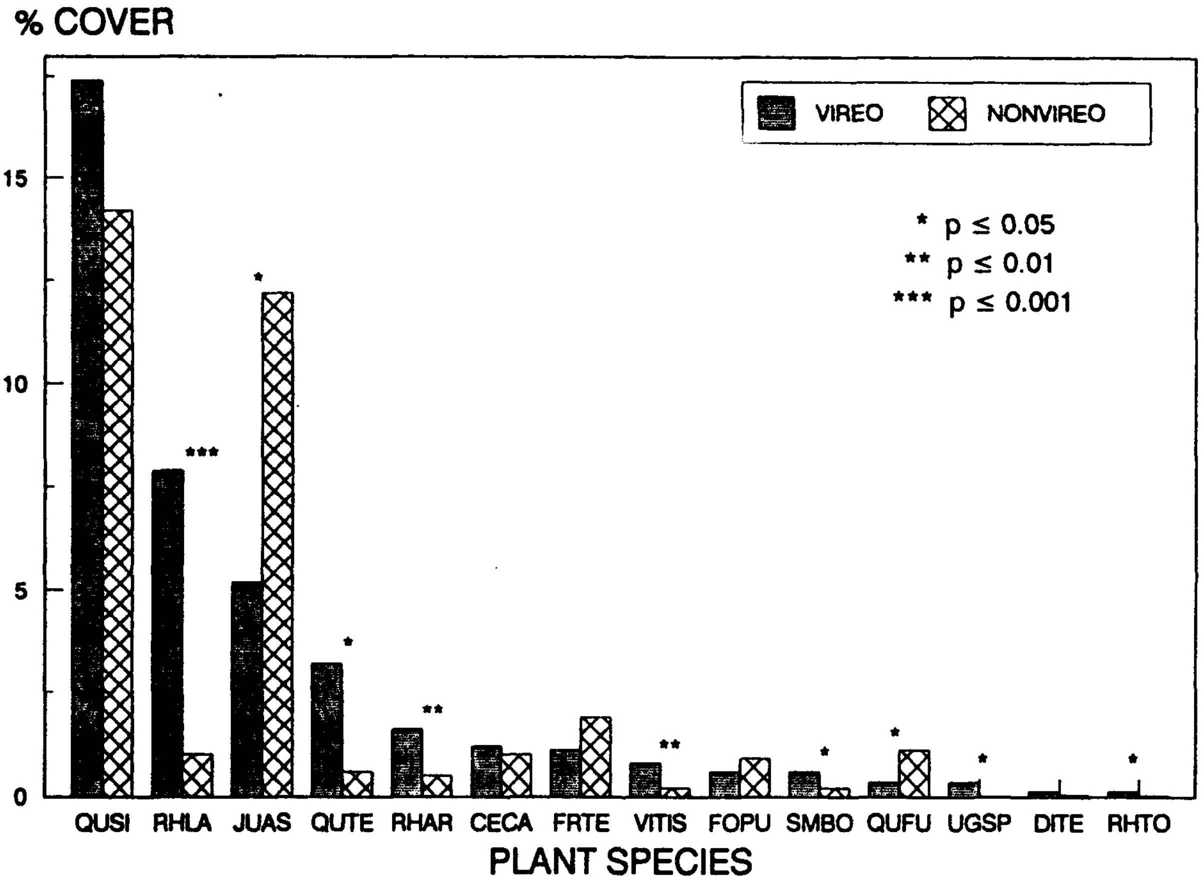


Figure 4. Layout of 0.04 ha Subplots Used for Vegetation Sampling.



Note: See Appendix B for plant species code descriptions.

Figure 5. Comparison of the Percent Cover of Common Woody Species Between VIREO and NONVIREO Plots.

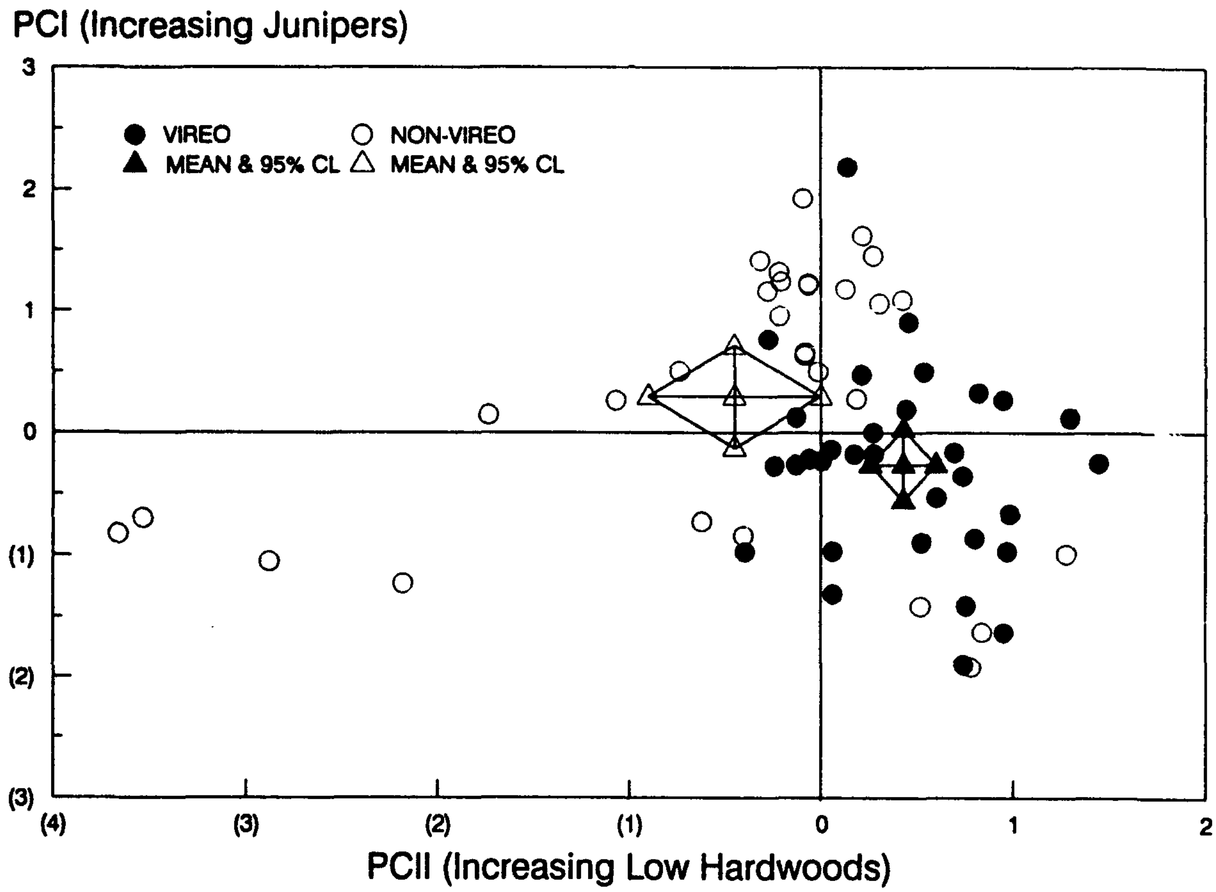
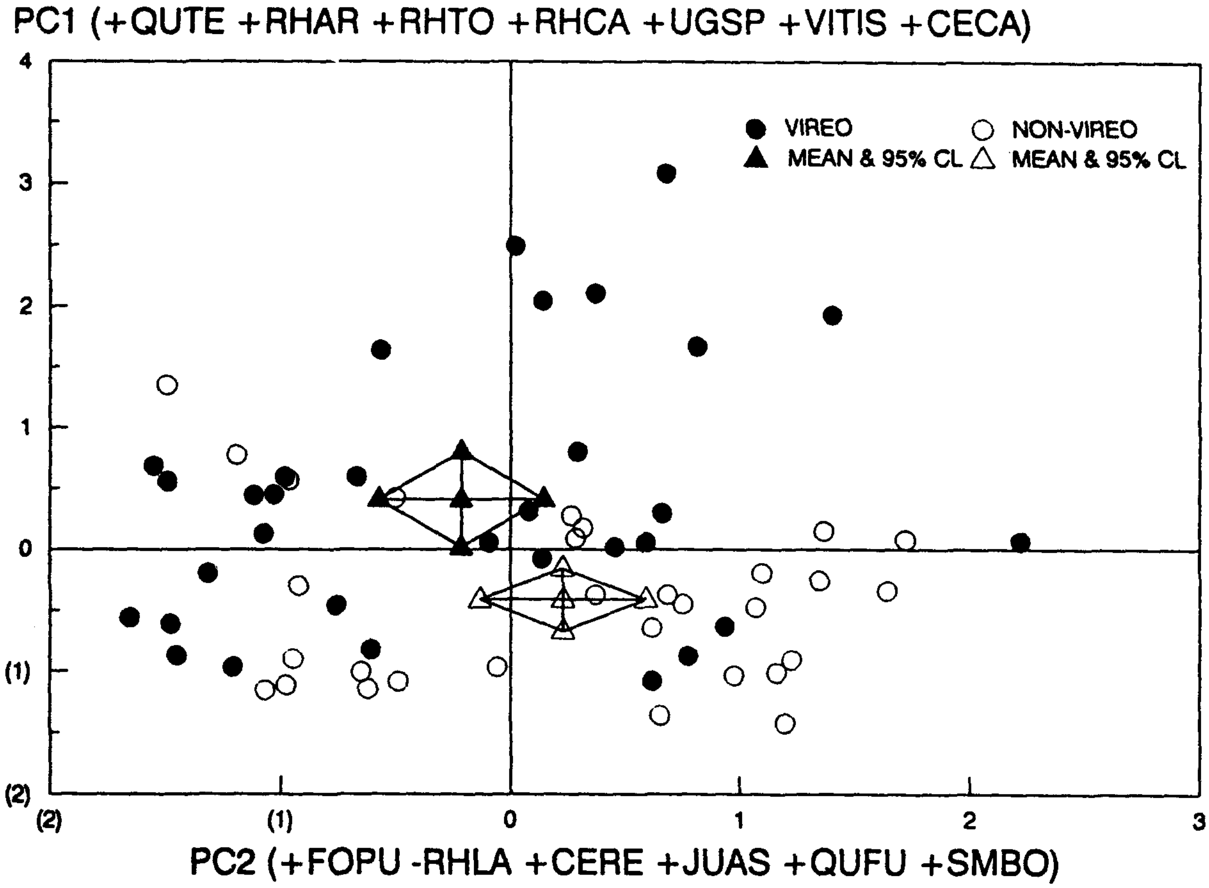


Figure 6. Results of Principal Component Analysis Using Habitat Structure Data.



Note: See Appendix B for plant species code descriptions.

Figure 7. Results of Principal Component Analysis Using Plant Species Cover Data.

APPENDIX B: Common Names, Species Codes, and Scientific Names of Plant Species Referenced in the Text

Common Name	Species Code	Scientific Name
Woody		
Ashe Juniper	JUAS	*Juniperus ashei*
Blackjack Oak	QUMA	*Qercus marilandica*
Carolina Buckthorne	RHCA	*Rhamnus caroliniana*
Cedar Elm	ULCR	*Ulmus crassifolia*
Deciduous Holly	ILDE	*Ilex decidua*
Elbow Bush	FOPU	*Foresteria pubescens*
Eve's Necklace	SOAF	*Sophora affinis*
Evergreen Sumac	RHVI	*Rhus virens*
False Willow	BASA	*Baccharis salicina*
Flame-leaved Sumac	RHLA	*Rhus lanceolata*
Grape	VITIS	*Vitis spp.*
Greenbriar	SMBO	*Smilax bona-nox*
Gum Bumelia	BULA	*Bumelia lanuginosa*
Live Oak	QUFU	*Quercus fusiformis*
Mexican Buckeye	UGSP	*Ugnadia speciosa*
Mexican Plum	PRME	*Prunus mexicana*
Mountain Laurel	SOSE	*Sophora secundiflora*
Netleaf Hackberry	CERE	*Celtis reticulata*
Poison Ivy	RHTO	*Rhus toxicodendron*
Post Oak	QUST	*Quercus stellata*
Red Bud	CECA	*Cercis canadensis*
Rusty Blackhaw	VIRU	*Viburnum rufidulum*
Shin Oak	QUSI	*Quercus sinuata*
Skunkbush Sumac	RHAR	*Rhus aromatica*
Texas Oak	QUTE	*Quercus texana*
Texas Persimmon	DITE	*Diospyros texana*
Texas Ashe	FRTE	*Fraxinus texensis*
Virginia Creeper	PAQU	*Parthenocissus quinquefolia*
White Honeysuckle	LOAL	*Lonicera albiflora*
Herbaceous		
Little Bluestem		*Schizachyrium scoparium*
Prairie Dropseed		*Sporobolus asper*
Texas Wintergrass		*Stipa leucotrichia*

APPENDIX C: Habitat Structure Variable Code Descriptions

Variable	Description
WOCVR	Percent woody cover
WOCVR_CV	Coefficient of variation (CV) for WOCVR
WOCVR_HARD	Percent hardwood cover
STEM	Total woody stems < 7.6 cm dbh at 1.5 m height/0.036 ha
STEM_CV	CV for STEM
STEM_JL	Live juniper stems < 7.6 cm dbh at 1.5 m height/0.036 ha
STEM_JD	Dead juniper stems < 7.6 cm dbh at 1.5 m height/0.036 ha
STEM_HL	Live hardwood stems < 7.6 cm dbh at 1.5 m height/0.036 ha
STEM_HD	Dead hardwood stems < 7.6 cm dbh at 1.5 m height/0.036 ha
STEM_DD	Dead stems < 7.6 cm dbh at 1.5 m height/0.036 ha
TREE	Total trees ≥ 7.6 cm dbh/0.24 ha
TREE_CV	CV for TREE
TREE_JL	Live juniper trees ≥ 7.6 cm dbh/0.24 ha
TREE_JD	Dead juniper trees ≥ 7.6 cm dbh/0.24 ha
TREE_HL	Live hardwood trees ≥ 7.6 cm dbh/0.24 ha
TREE_HD	Dead hardwood trees ≥ 7.6 cm dbh/0.24 ha
TREE_DD	Dead trees ≥ 7.6 cm dbh/0.24 ha
TREE_JLA	Live juniper trees 7.6 cm to < 15.2 cm dbh/0.24 ha
TREE_JLB	Live juniper trees 15.2 cm to < 22.9 cm dbh/0.24 ha
TREE_JLC	Live juniper trees ≥ 22.9 cm dbh/0.24 ha
TREE_JDA	Dead juniper trees 7.6 cm to < 15.2 cm dbh/0.24 ha
TREE_JDB	Dead juniper trees 15.2 cm to < 22.9 cm dbh/0.24 ha
TREE_JDC	Dead juniper trees ≥ 22.9 cm dbh/0.24 ha
TREE_HLA	Live hardwood trees 7.6 cm to < 15.2 cm dbh/0.24 ha
TREE_HLB	Live hardwood trees 15.2 cm to < 22.9 cm dbh/0.24 ha
TREE_HLC	Live hardwood trees ≥ 22.9 cm dbh/0.24 ha
TREE_HDA	Dead hardwood trees 7.6 cm to < 15.2 cm dbh/0.24 ha
TREE_HDB	Dead hardwood trees 15.2 cm to < 22.9 cm dbh/0.24 ha
TREE_HDC	Dead hardwood trees ≥ 22.9 cm dbh/0.24 ha

APPENDIX C: (Cont'd)

Variable	Description
V5	Woody vegetation hits in decimeter intervals 1 thru 5
V10	Woody vegetation hits in decimeter intervals 6 thru 10
V15	Woody vegetation hits in decimeter intervals 11 thru 15
V20	Woody vegetation hits in decimeter intervals 15 thru 20
V25	Woody vegetation hits in decimeter intervals 20 thru 25
V30	Woody vegetation hits in decimeter intervals 25 thru 30
V40	Woody vegetation hits in decimeter intervals 30 thru 40
V50	Woody vegetation hits in decimeter intervals 40 thru 50
V60	Woody vegetation hits in decimeter intervals 51 thru 60
V70	Woody vegetation hits in decimeter intervals 61 thru 70
V70+	Woody vegetation hits in decimeter intervals over 70
VLT30_CV	CV for woody vegetation hits in decimeter intervals ≤ 30
VGT30_CV	CV for in woody vegetation hits in decimeter intervals > 30
VGRAS	Sum of all grass hits
VFORB	Sum of all forb hits
WOOD	Percent woody ground cover
GRAS	Percent grass ground cover
FORB	Percent forb ground cover
ROCK	Percent rocky ground cover
CACT	Percent cactus ground cover
TRAC	Percent vehicle tracking on ground

APPENDIX D: Colony Site Code Descriptions

Non-Live Training Area

AR2T	Area 2-Top
AR2S	Area 2-Slope
AR 6	Area 6
AR 12	Area 12
REBL	Red Bluff
BHMT	Brookhaven Mountain
MAMT	Manning Mountain
WMSP	Williamson Mountain
WMSP	Shell Point
NWFH	Northwest Fort Hood
WEFH	West Fort Hood

Live Fire Training Area

AR 75	Area 75
ROPT	Robinette Point
RAPT	Rambo Point
BRCR	Brown's Creek
JAMT	Jack Mountain
NOLF	Ruth Cemetery
NOLF	Dalton Mountain
NOLF	Henson Mountain
LOMT	Lone Mountain
PKRA	Pilot Knob Range
AR 81	Area 81

APPENDIX E: Plant Community Code Descriptions

BARR	Barren; <10% ground cover
SPHE	Sparse Herbaceous
SPFO	Sparse Forb
OPFO	Open Forb
DEFO	Dense Forb
CLFO	Closed Forb
SPGR	Sparse Grass
OPGR	Open Grass
DEGR	Dense Grass
CLGR	Closed Grass
OPSH	Open Shrub
DESH	Dense Shrub
CLSH	Closed Woodland
OPWO	Open Woodland
DEWO	Dense Woodland
CLWO	Closed Woodland

Sparse:	<25% cover
Open:	25 to 50% cover
Dense:	51 to 75% cover
Closed:	76 to 100% cover

ABBREVIATIONS AND ACRONYMS

CAD	canonical analysis of discriminance
CAN1	first canonical variat
E'	evenness
EL	Environmental Sustainment Laboratory
EN	Natural Resources Division
FAD	funding authorization document
H'	Shannon's Index
HQ	headquarters
IAO	Intra-Agency order
LCTA	Land Condition-Trend Analysis
MIPR	Military Interdepartmental Purchase Request
PC	principal component
PCA	principal component analysis
SAS	Statistical Analysis System
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratories

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